



Introduction to Carbonate Rock

Source Material from Prof. Chris Kendall (University of South Carolina)



Precipitated Sediments & Sedimentary Rocks

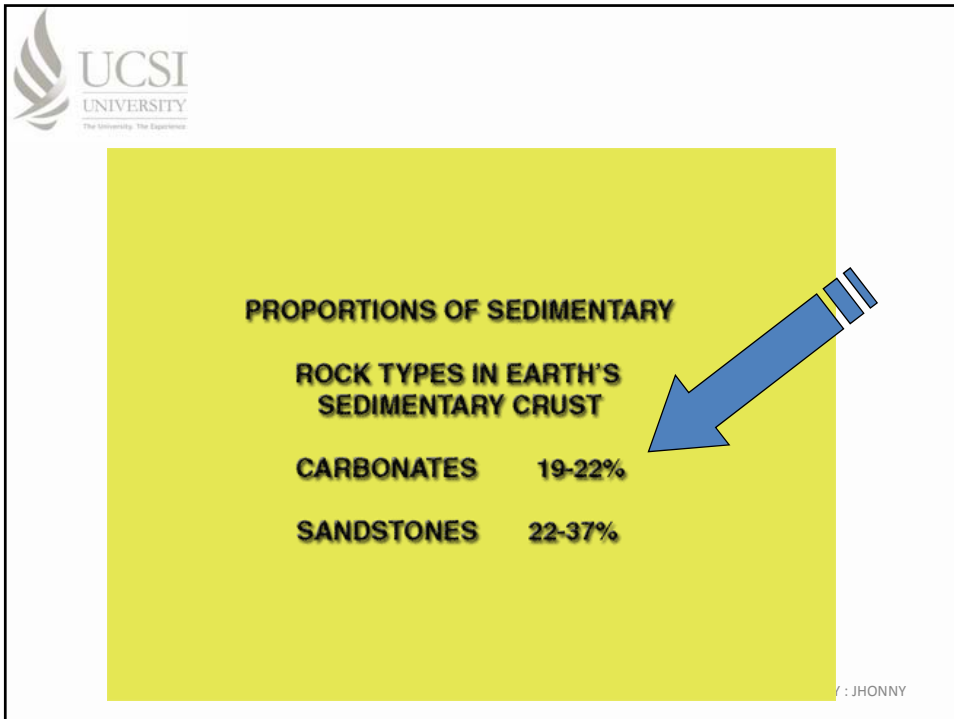
An Epitaph to Limestones & Dolomites



Sedimentary rocks are the product of the creation, transport, deposition, and diagenesis of detritus and solutes derived from pre-existing rocks.



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Limestones Form - Where?

- Shallow Marine – *Late Proterozoic to Modern*
- Deep Marine – *Rare in Ancient & commoner in Modern*
- Cave Travertine and Spring Tufa – *both Ancient & Modern*
- Lakes – *Ancient to Modern*

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CO₂ - Temperature & Pressure Effect!

- High **temperatures**, low **pressure** & breaking waves favor carbonate precipitation
- $\text{CO}_2 + 3\text{H}_2\text{O} = \text{HCO}_3^{-1} + \text{H}_3\text{O}^{+1} + \text{H}_2\text{O} = \text{CO}_3^{-2} + 2\text{H}_3\text{O}^{+1}$
- Carbon dioxide solubility decreases in shallow water and with rising in **temperature**
- At lower **pressure** CO₂ is released & at higher **pressure** dissolves
- HCO₃⁻¹ and CO₃⁻² are less stable at lower **pressure** but more stable at higher **pressure**
- HCO₃⁻¹ and CO₃⁻² have lower concentration in **warm** waters but higher concentrations in colder waters

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Calcium Carbonate - Solubility

- Note calcium carbonate dissociation: $\text{CaCO}_3 = \text{Ca}^{+2} + \text{CO}_3^{-2}$
- CaCO₃ is less soluble in warm waters than cool waters
- CaCO₃ precipitates in warm shallow waters but is increasingly soluble at depth in colder waters
- CO₂ in solution buffers concentration of carbonate ion (CO₃⁻²)
- Increasing pressure elevates concentrations of HCO₃⁻¹ & CO₃⁻² (products of solubility reaction) in sea water
- CaCO₃ more soluble at higher pressures & with decreasing temperature

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Controls on Carbonate Accumulation

- Temperature (climate) - *Tropics & temperate regions favor carbonate production: true of ancient too!*
- Light – *Photosynthesis drives carbonate production*
- Pressure – *“CCD” dissolution increases with depth*
- Agitation of waves - *Oxygen source & remove CO₂*
- Organic activity - *CaCO₃ factories nutrient deserts*
- Sea Level – *Yield high at SL that constantly changes*

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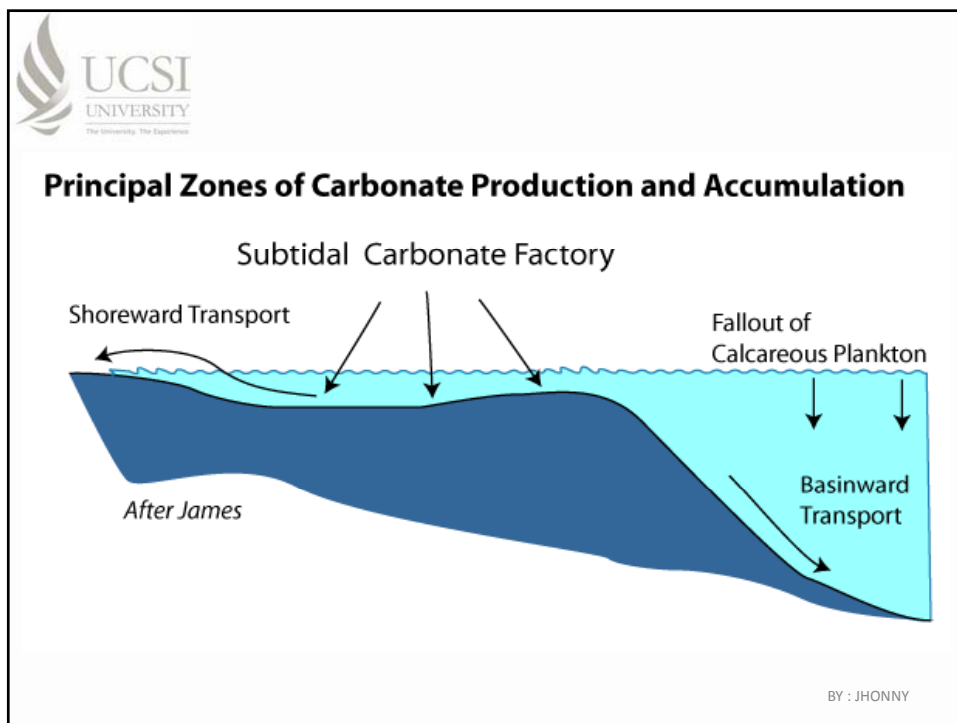
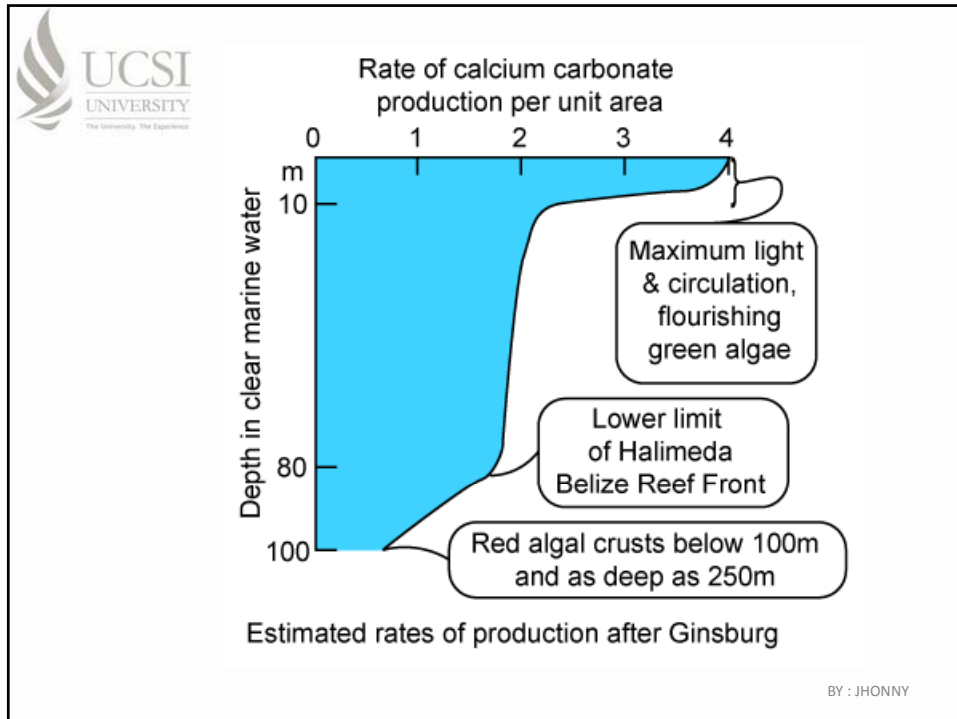
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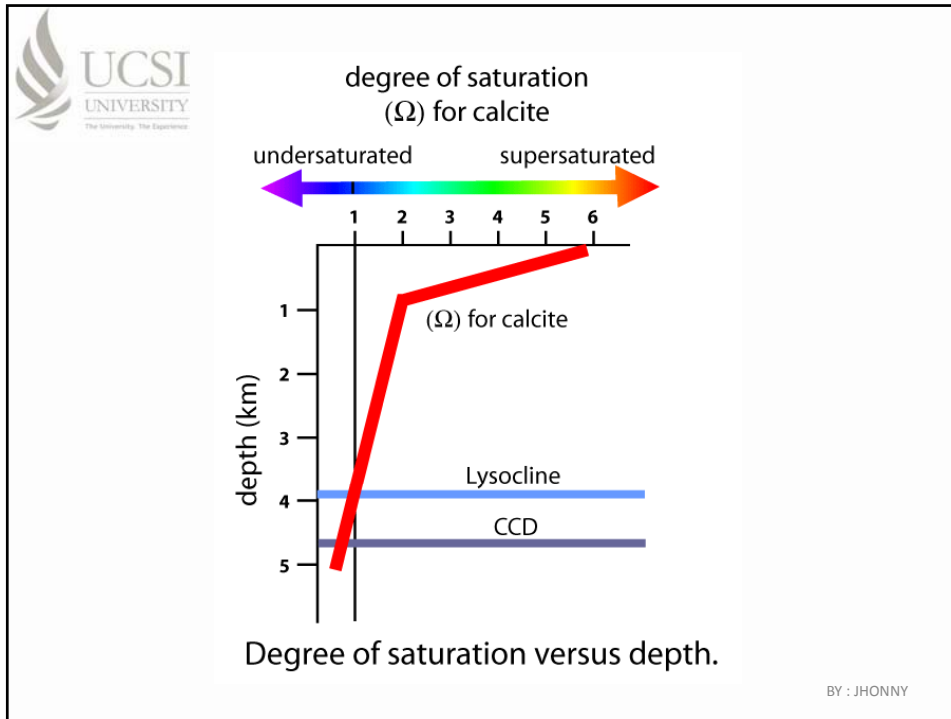
Limestones – Chemical or Biochemical

Distinction between biochemical & physico-chemical blurred by ubiquitous cyanobacteria of biosphere!

- Shallow sea water is commonly saturated with respect to calcium carbonate
- Dissolved ions expected to be precipitated as sea water warms, loses CO₂ & evaporates
- Organisms generate shells & skeletons from dissolved ions
- Metabolism of organisms cause carbonate precipitation

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Biological Carbon Pump

- Carbon from CO_2 incorporated in organisms through photosynthesis, heterotrophy & secretion of shells
- > 99% of atmospheric CO_2 from volcanism removed by biological pump is deposited as calcium carbonate & organic matter
- 5.3 gigatons of CO_2 added to atmosphere a year but only 2.1 gigatons/year remains; the rest is believed sequestered as aragonite & calcite

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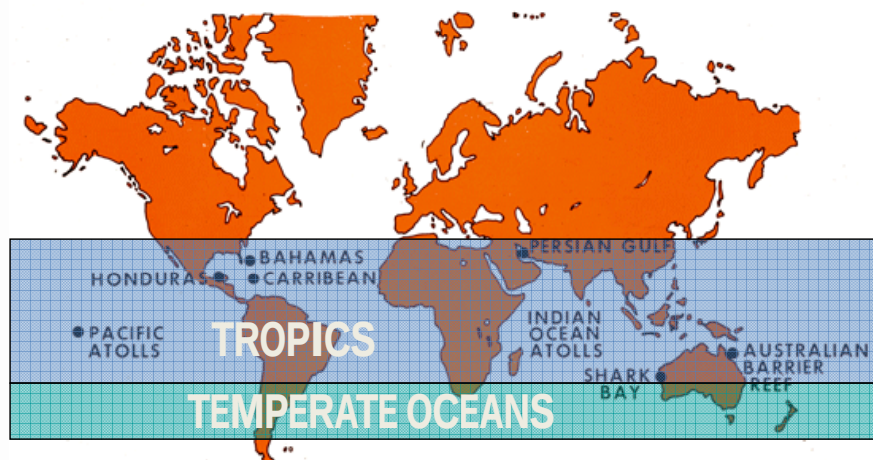
Carbonate Mineralogy

- Aragonite – high temperature mineral
- Calcite – stable in sea water & near surface crust
 - Low Magnesium Calcite
 - High Magnesium Calcite
 - Imperforate foraminifera
 - Echinoidea
- Dolomite – stable in sea water & near surface
- Carbonate mineralogy of oceans changes with time!

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AREAS OF MODERN CARBONATE DEPOSITION



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Depositional Setting	Type of Deposit
Basin and slope	Pelagic sediments Turbidites and debris flows
Platform margin	Reefs and organic buildups Sand shoals
Platform interior	Epeiric sea, lagoon or bay Tidal flats
Terrestrial	Dunes, lakes, cave deposits, soils, fanglomerates

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Carbonate Components – The Key

- Interpretation of depositional setting of carbonates is based on
 - Grain types
 - Grain packing or fabric
 - Sedimentary structures
 - Early diagenetic changes
- Identification of grain types commonly used in subsurface studies of depositional setting because, unlike particles in siliciclastic rocks, carbonate grains generally formed within basin of deposition
- **NB:** This rule of thumb doesn't always apply

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Carbonate Particles

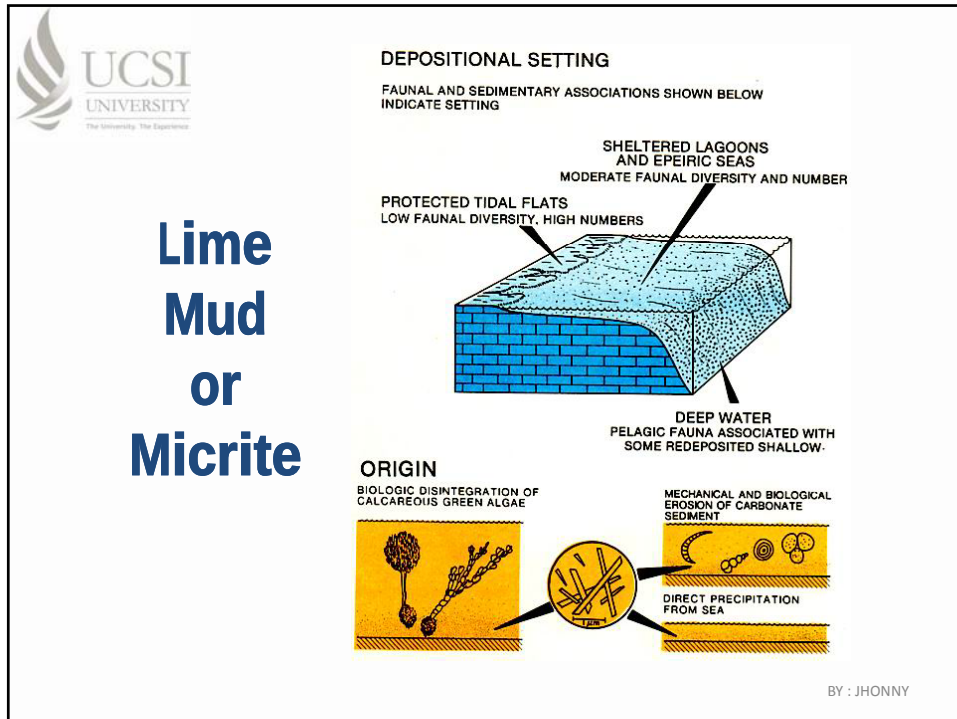
- Subdivided into micrite (lime mud) & sand-sized grains
- These grains are separated on basis of shape & internal structure
- They are subdivided into: skeletal & non-skeletal (bio-physico-chemical grains)

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Lime Mud or Micrite

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Three Creeks Tidal Flats



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Lime Mud - Ordovician Kentucky



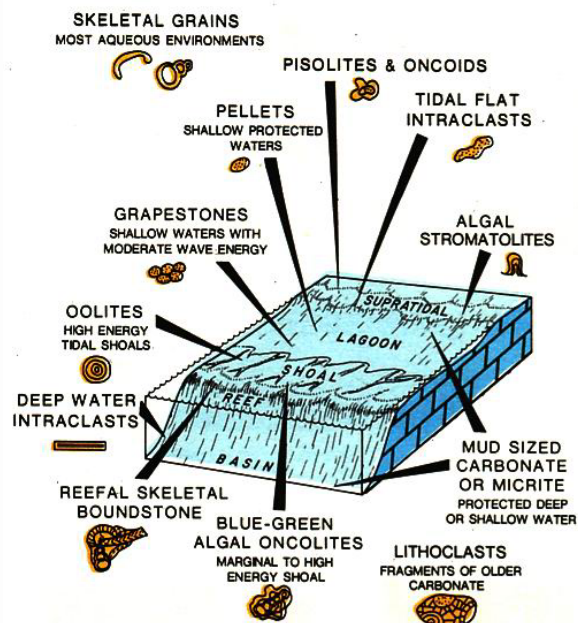
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Carbonate Bio-physico-chemical Grains

- Ooids
- Grapestones and other intraclasts
- Pellets
- Pisolites and Oncolites

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CEMENTATION DURING SEDIMENT DEPOSITION

MARINE ENVIRONMENT:

1. FORMATION OF	} OOLITES GRAPESTONES PELLET HARDENING
2. SUBMARINE	
	A. REEF CAVITY CEMENT B. SEDIMENT SURFACE CRUSTS
3. INTERTIDAL	A. SUBSURFACE CRUSTS B. SEDIMENT SURFACE CRUSTS

STABLE MARINE CEMENTS:

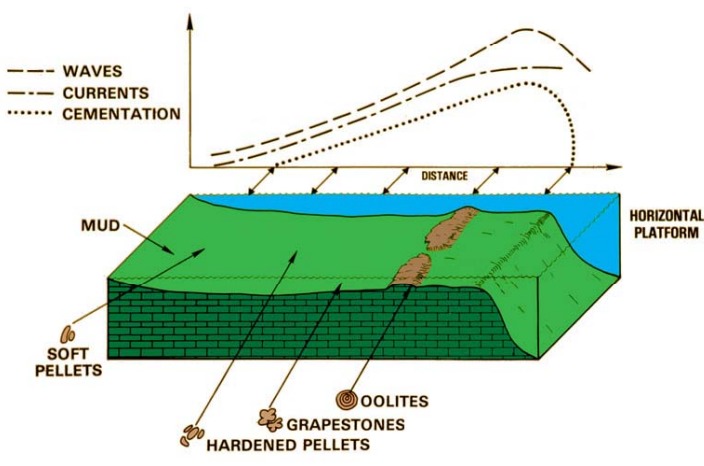
ARAGONITE ——— FIBERS, AND MICRITE

HIGH MAGNESIUM CALCITE ——— FIBERS, BLADES AND MICRITE

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RELATIONSHIP OF GRAIN MORPHOLOGY TO CEMENTATION AND WAVE AND CURRENT REGIME



--- WAVES
--- CURRENTS
..... CEMENTATION

DISTANCE

MUD

HORIZONTAL PLATFORM

SOFT PELLETS

OOLITES

GRAPESTONES

HARDENED PELLETS

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